Locomotive Emissions & Efficiency Technology Roadmaps

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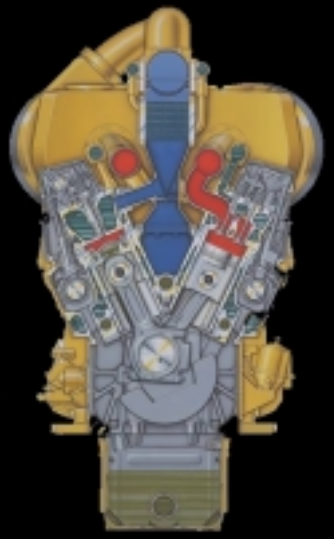
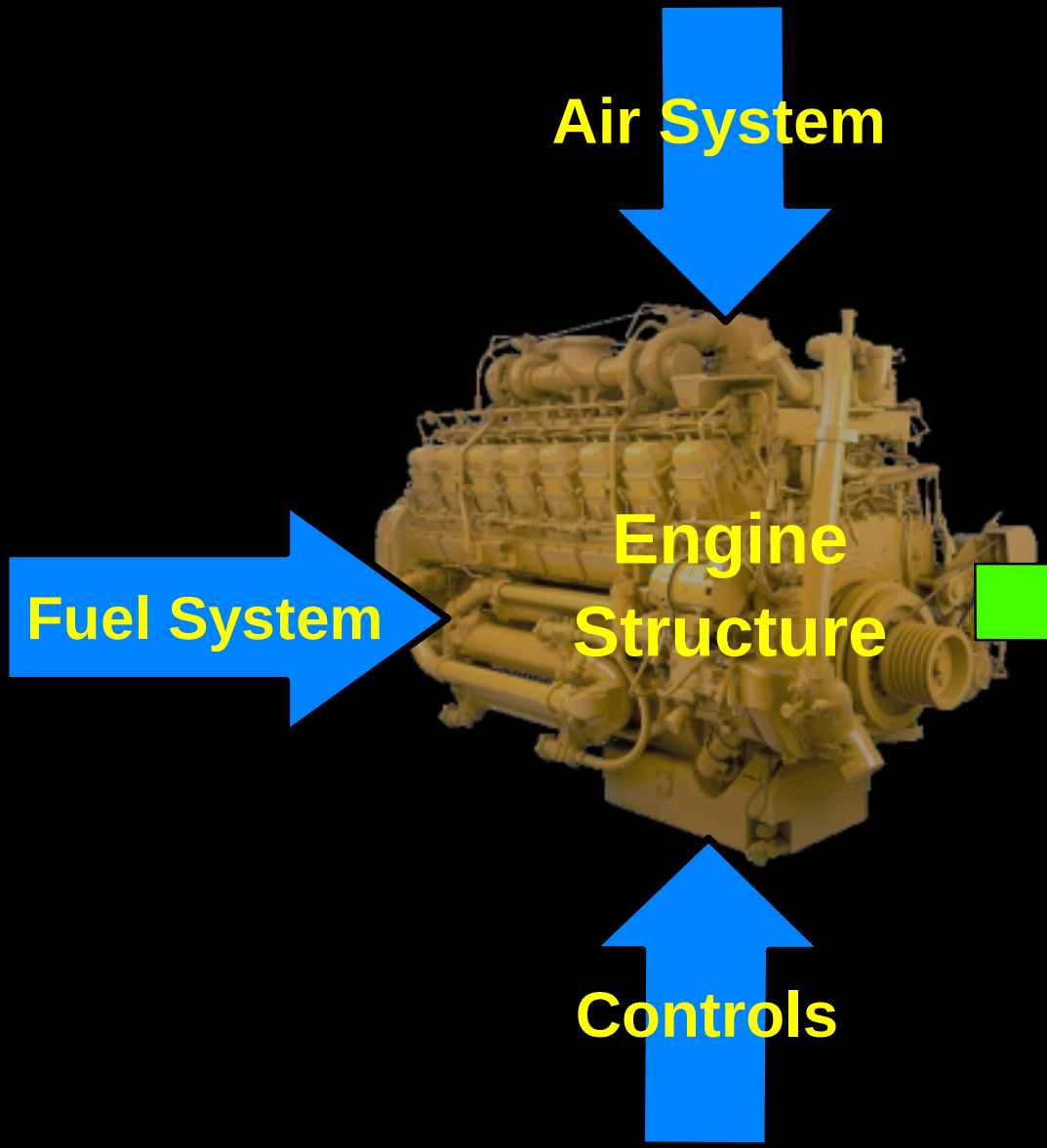
New Technology Introduction Manager

Locomotive Emissions and
Systems Efficiency Workshop
31-Jan-01



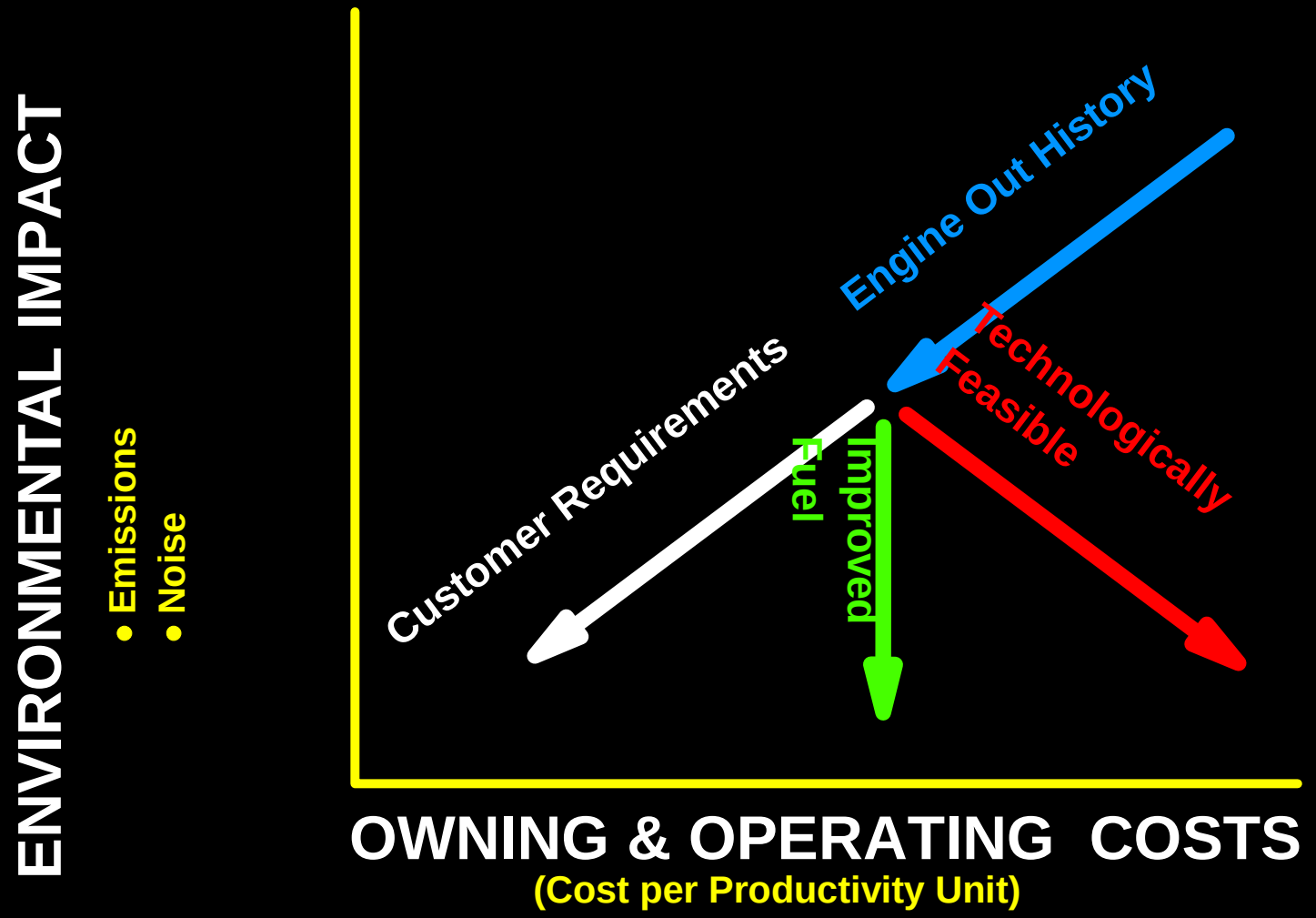
CATERPILLAR®

Key Technologies

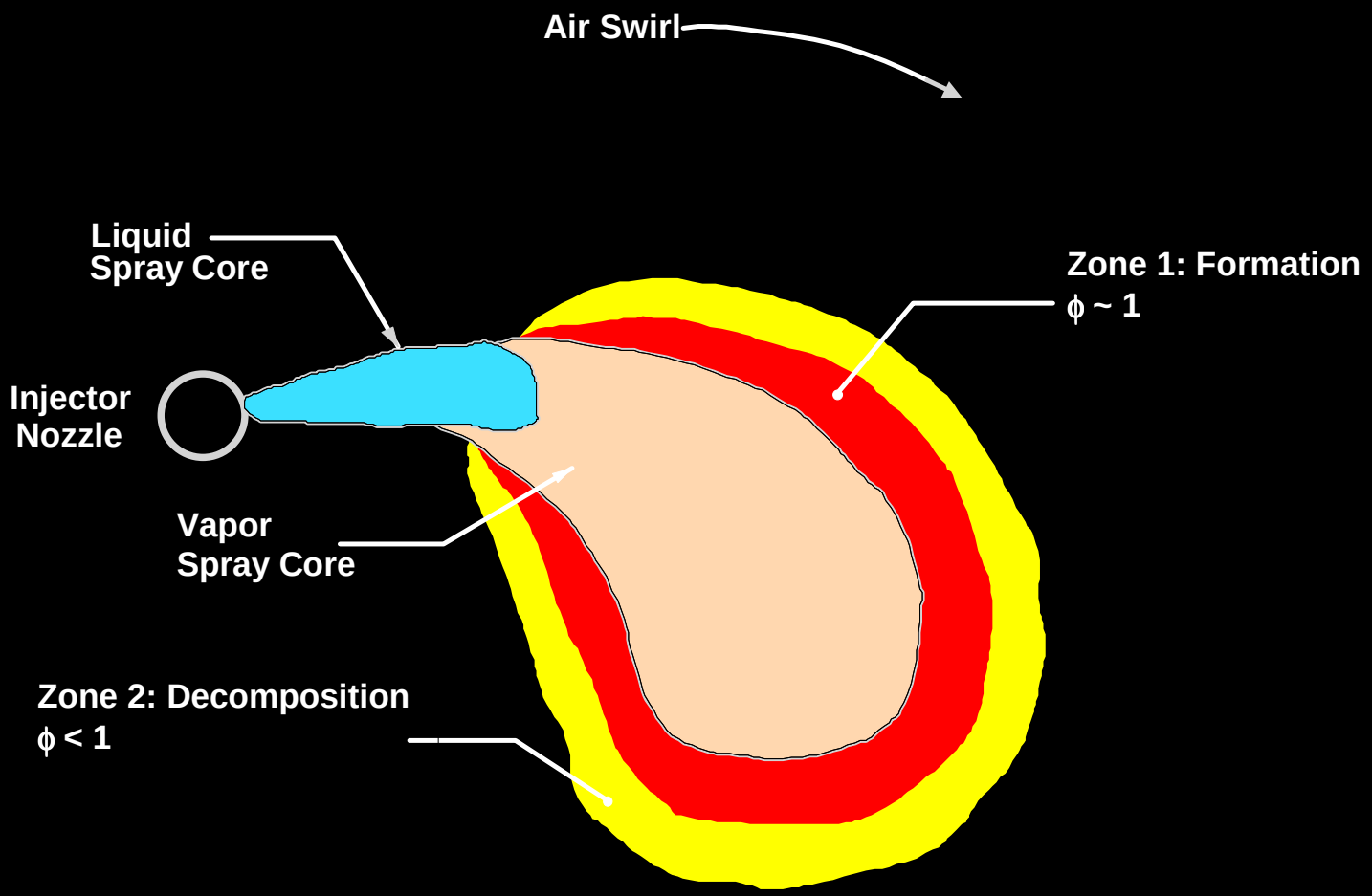


- Emissions
- Efficiency
- Reliability
- Durability
- L/C Cost

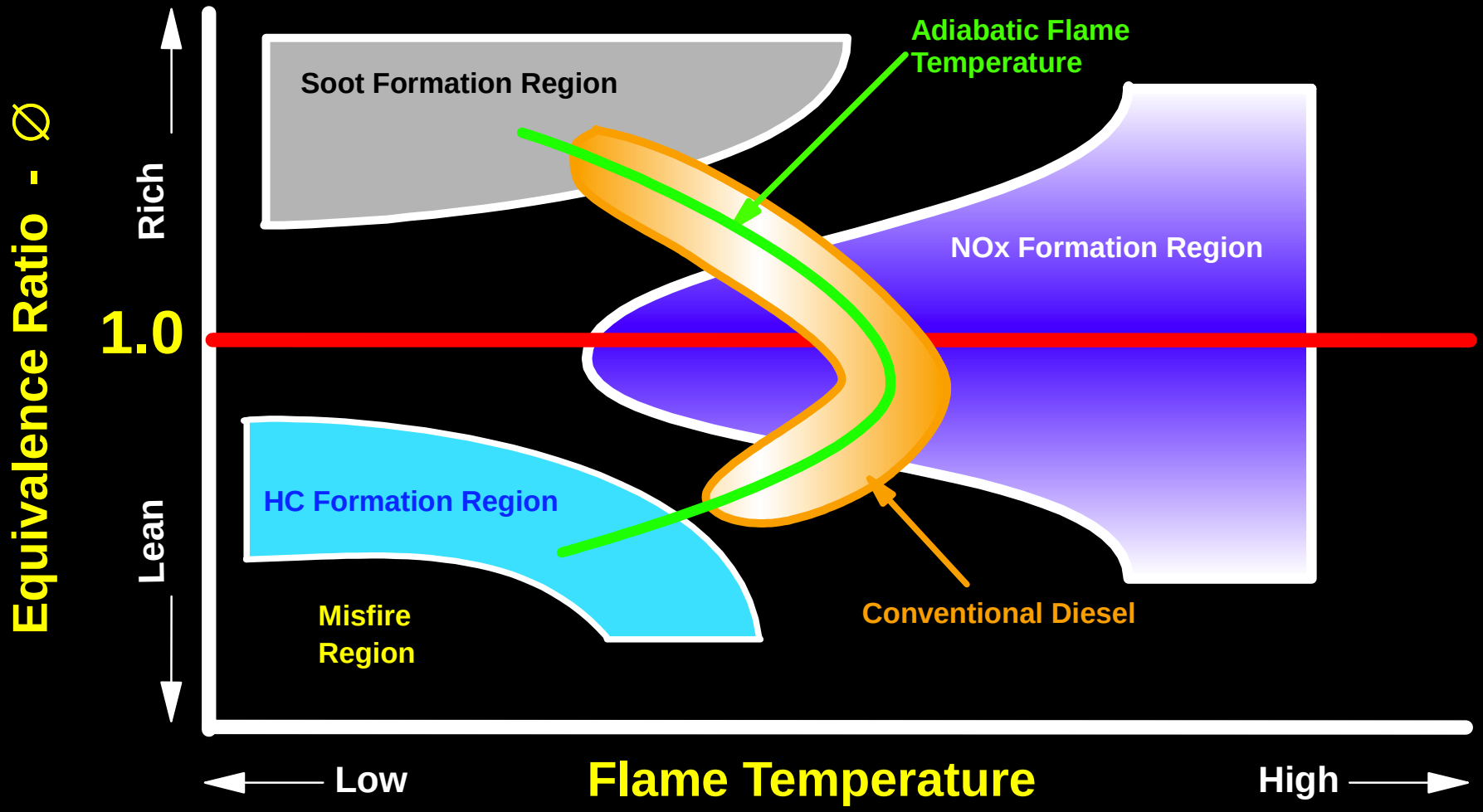
Owning & Operating Trends



NO_x Formation - Diesel

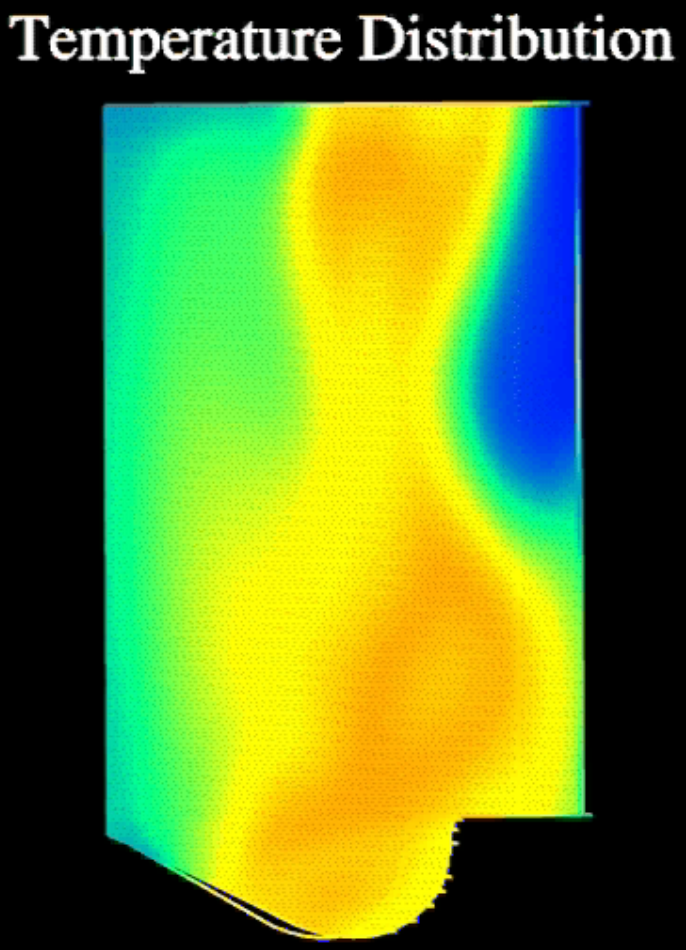


Diesel Combustion

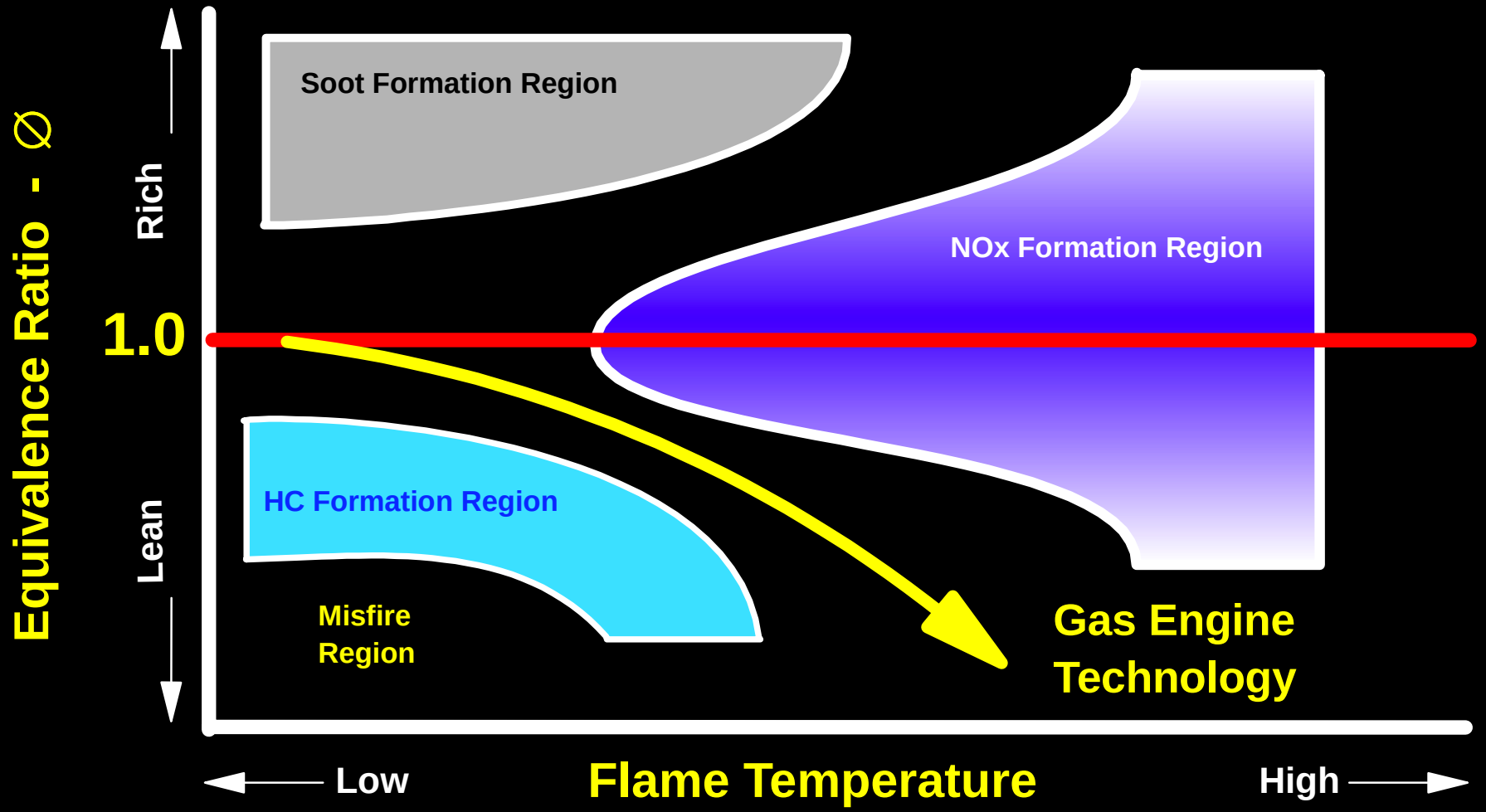


Combustion Modeling Program

- Advanced Analysis:
  - **Performance Analysis**
  - **Combustion Simulation**
- Advanced Design:
  - **Genetic Algorithms**
  - **Design Optimization**
- Partnerships
  - **U. of Wisconsin**
  - **.....**



Gas Engine Combustion



Gas Engine Application to Locomotives

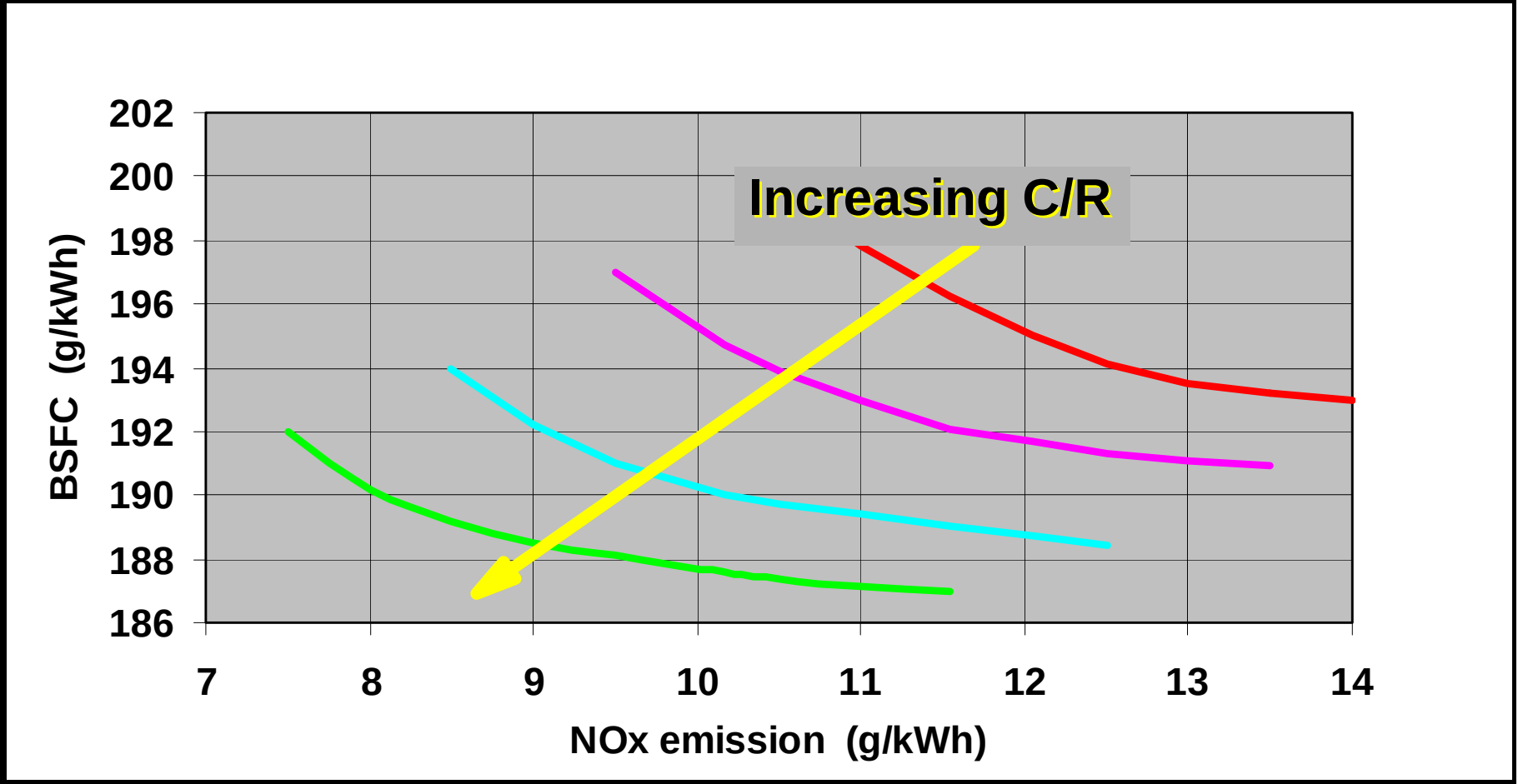
- **Advantages**
  - Low Emissions
    - <1.0 gm NO_x
    - Low Particulates
- **Increased Efficiency**
  - Linkage w/ ARES Program
  - Target 50% Thermal Efficiency

"Inside The Engine" Technology

M43 Cylinder Liner

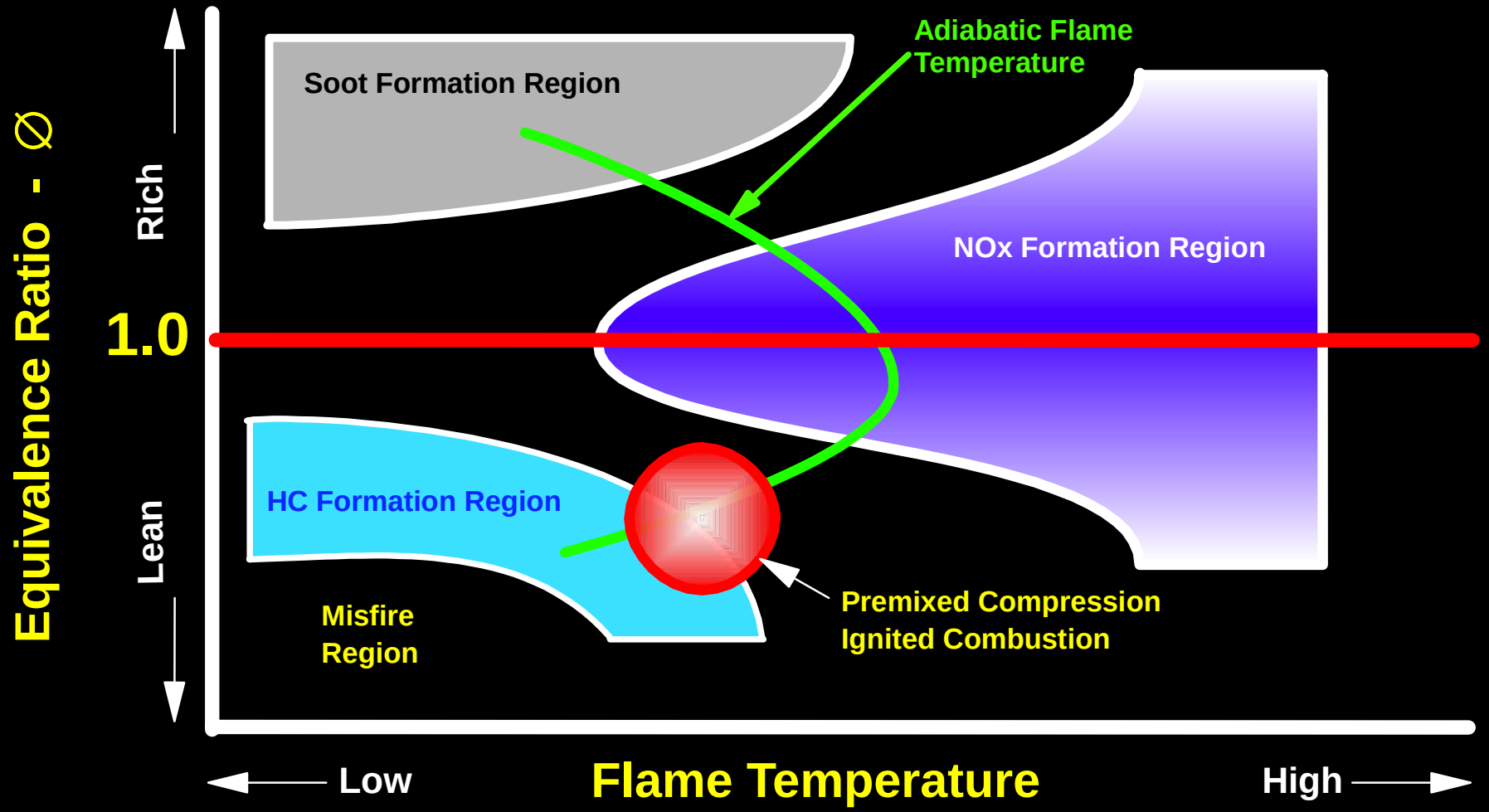
Compression Ratio Effect

With Miller Cycle

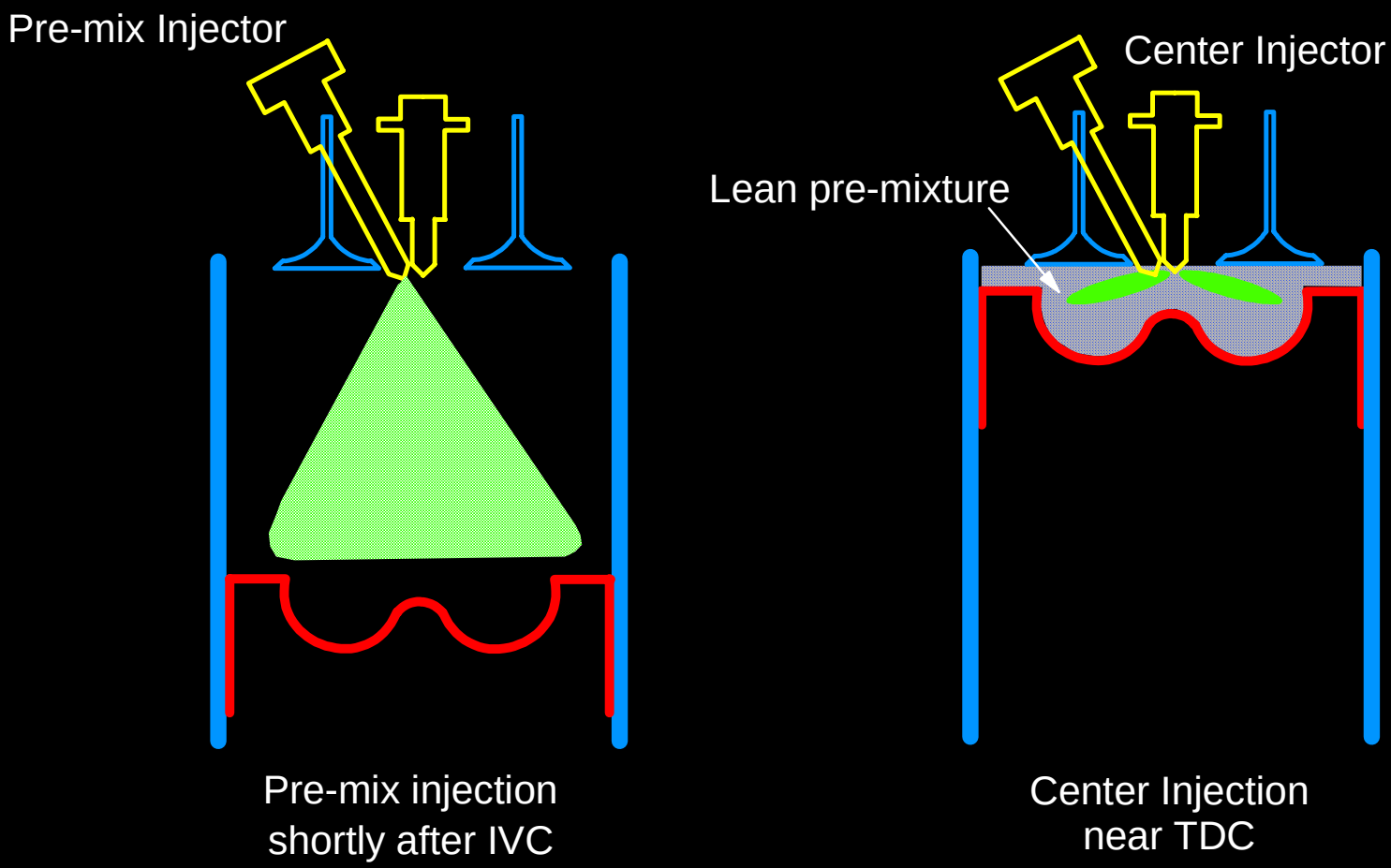


Diesel HCCI

Homogeneous Charge Compression Ignition



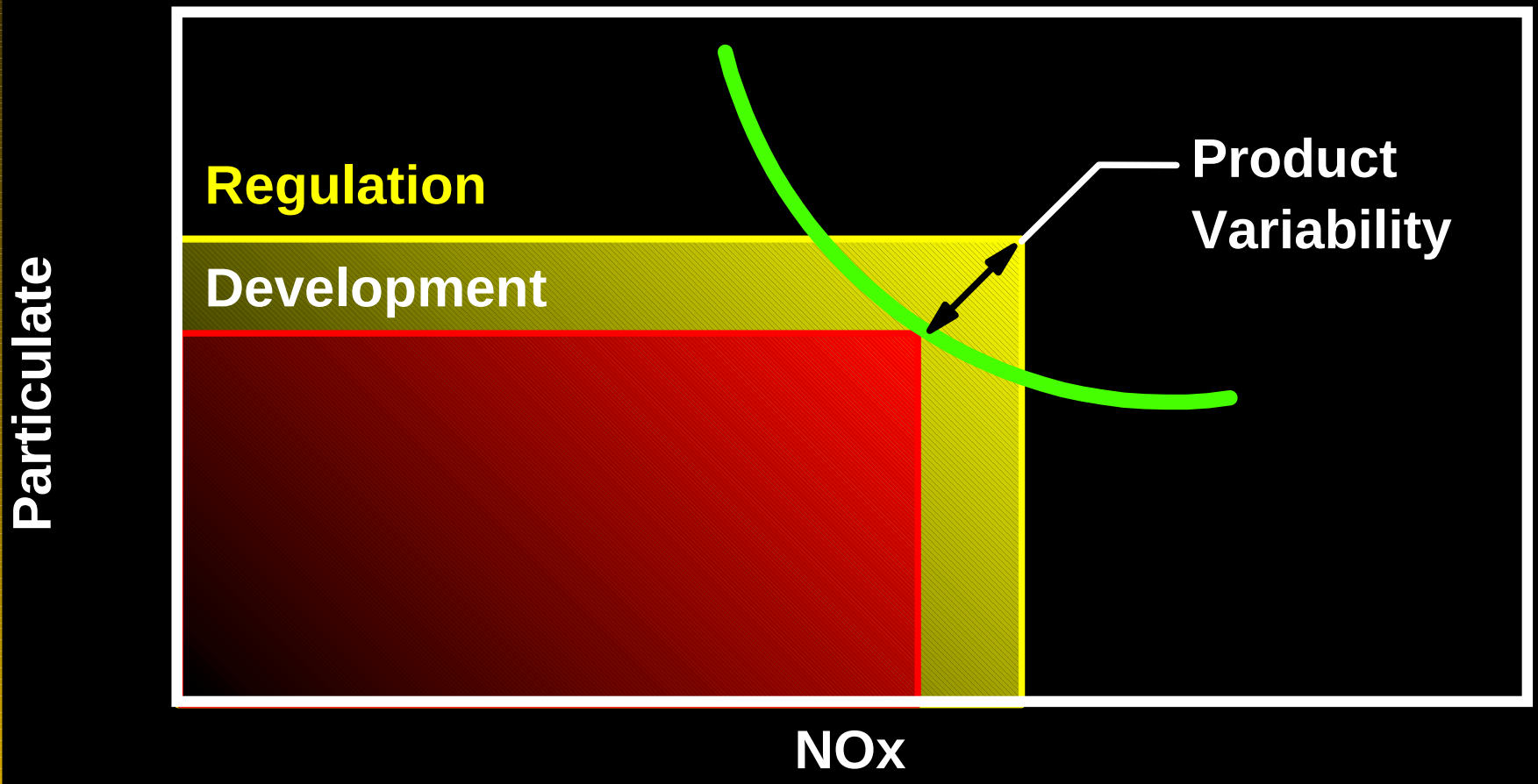
HCCI - Two Stage Injection



Diesel HCCI Technology Need

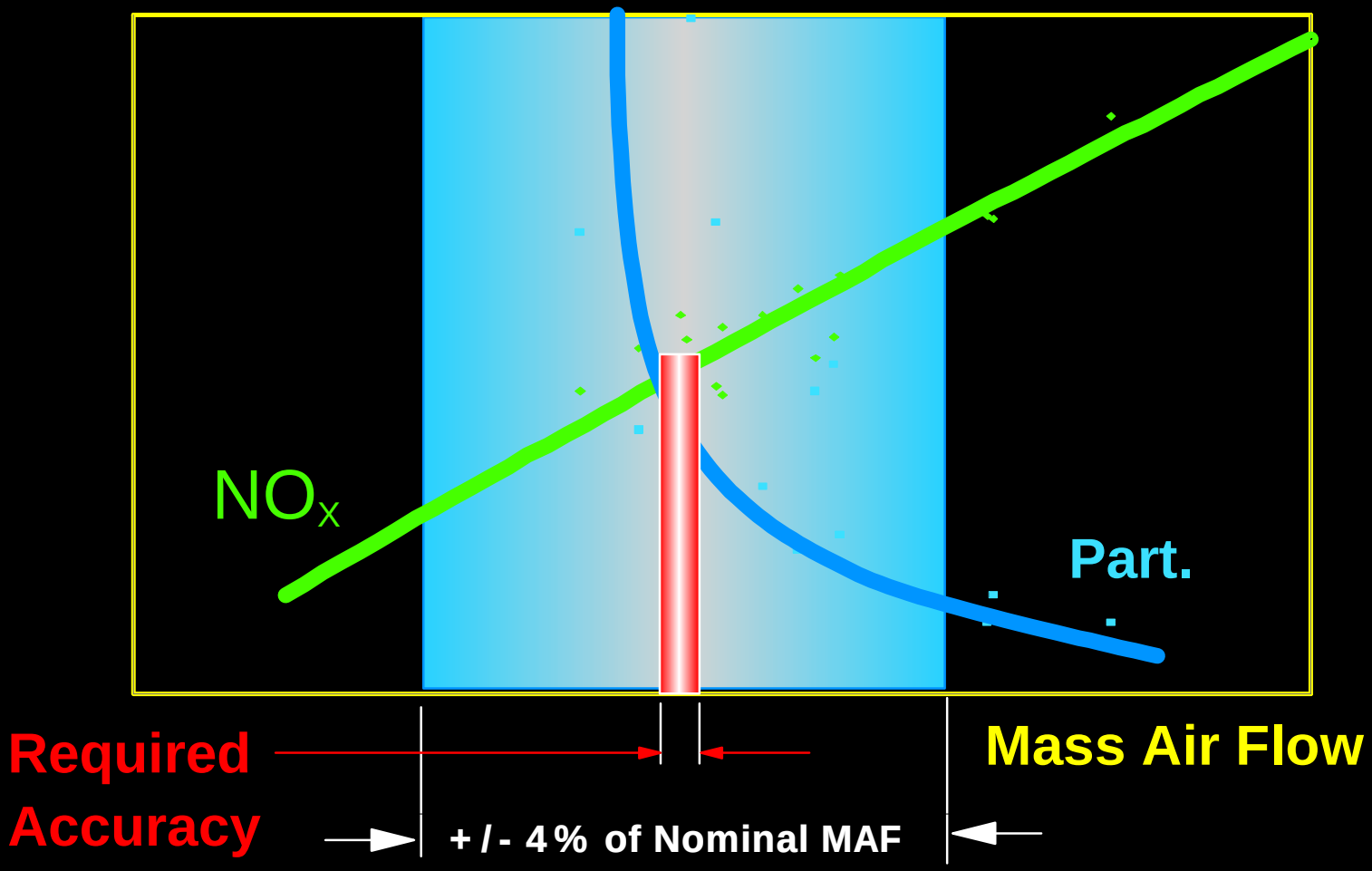
- **Single Injector**
  - Variable Orifice Spray Pattern
    - Size / Direction
    - On / Off
    - Current Package Size
- **Needed For Retro-Fit**

Technology / Variability Gap

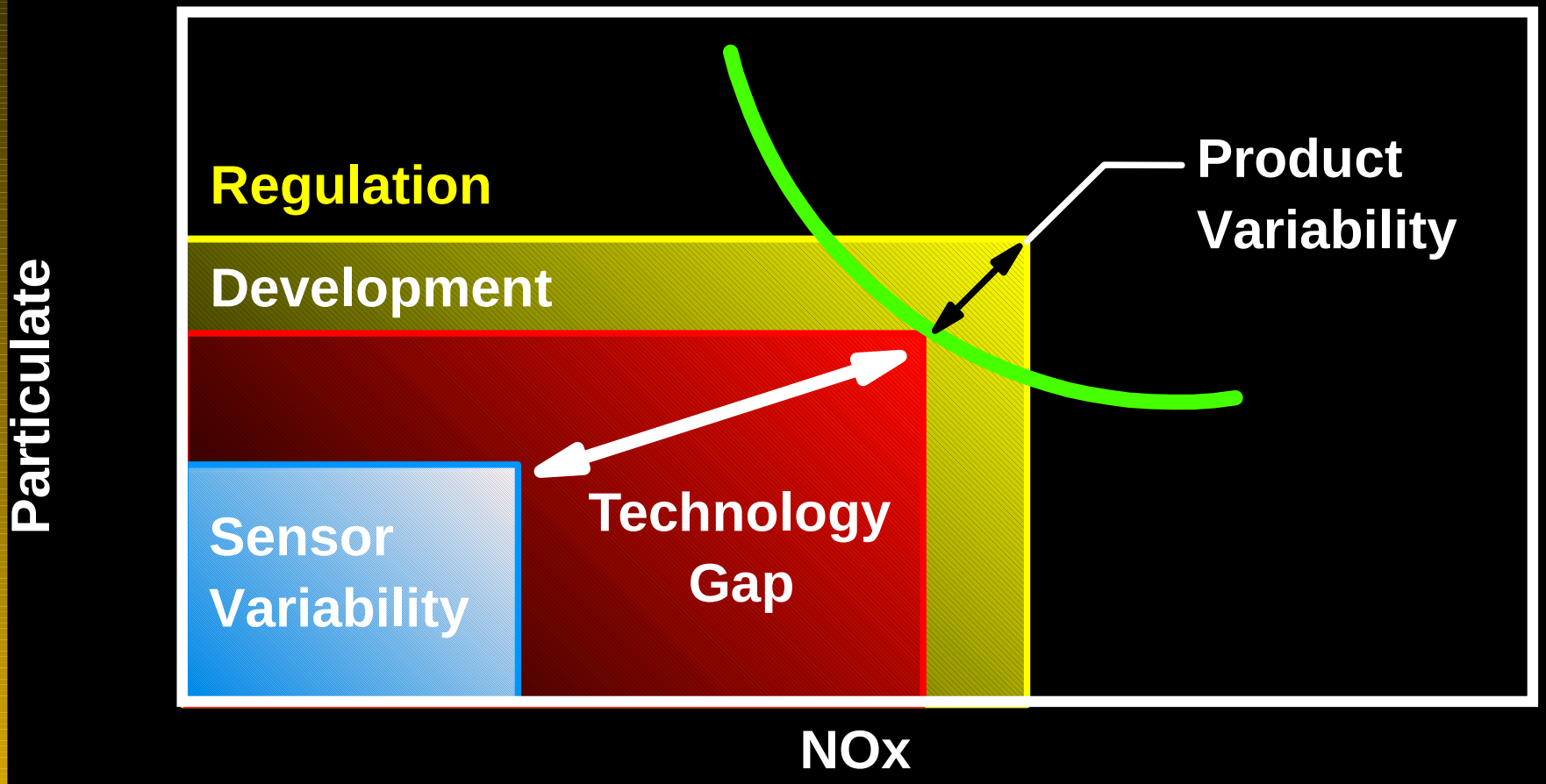


EGR Sensor Accuracy

Impact On Emissions



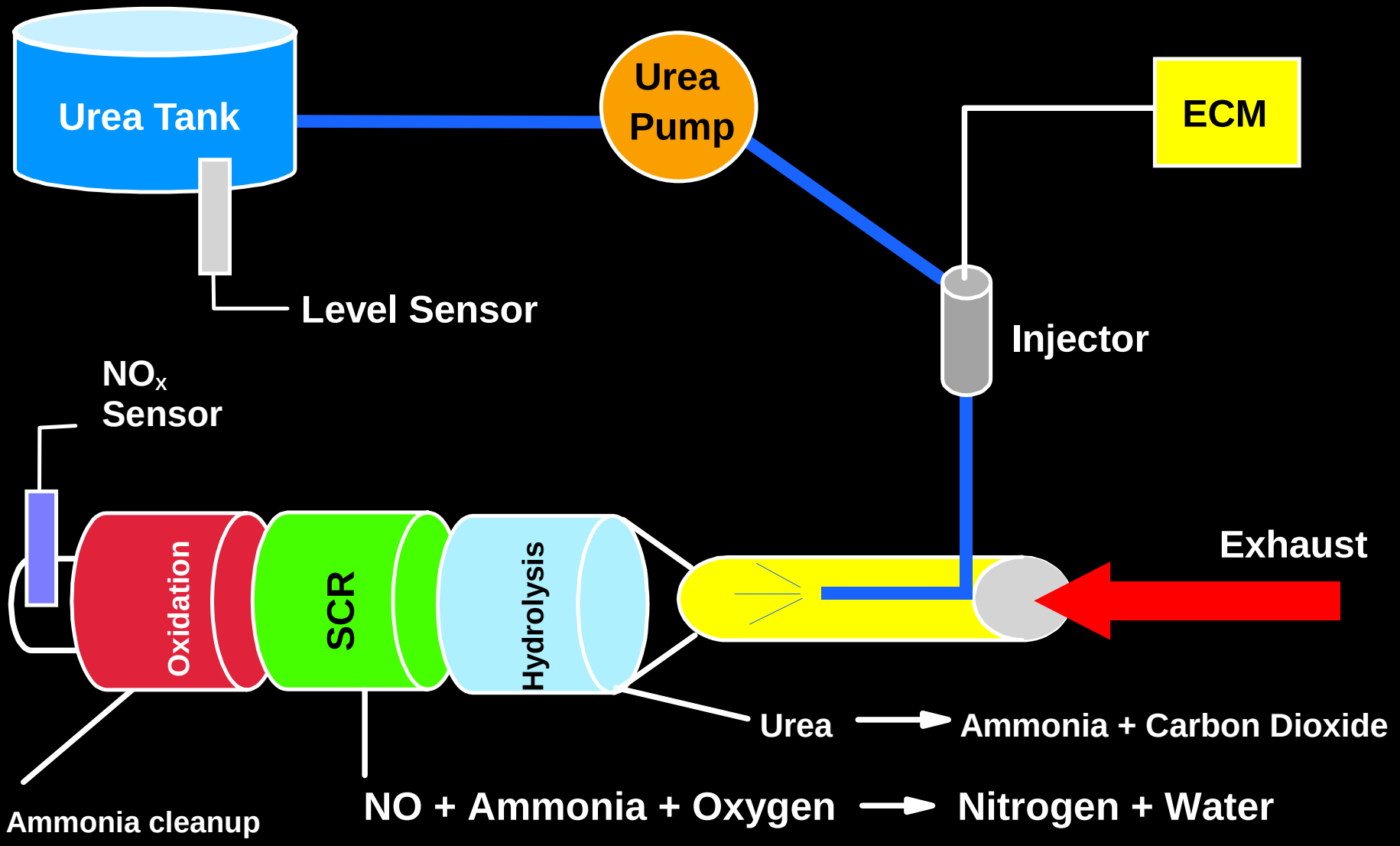
Technology / Variability Gap



After-Treatment Technology

Technology	Emissions Reductions	Hurdles
Oxidation Catalyst	Particulates 10-30%	Low Sulfur Fuel, +Cost
Particulate Trap	Particulates 90+%	Large Size (2x), +++Cost
SCR	NOx 70-90%	Ammonia or Urea, +++Cost
NOx Trap	NOx 40-60%	EPA Perception 90+% Regen Fuel 5-10% bsfc Zero Sulfur Fuel
Lean NOx Catalyst	NOx 20-30%	Large Size (2x) 3-8% bsfc +++Cost
Plasma System	Part / NOx? 70-90%	Undeveloped

SCR System


Urea Tank
Urea Pump
ECM
Level Sensor
Injector
NO_x Sensor
Oxidation
SCR
Hydrolysis
Exhaust
Urea → Ammonia + Carbon Dioxide
Ammonia cleanup
NO + Ammonia + Oxygen → Nitrogen + Water

Ultra Fast NO_x Sensor - Benefits

- Closed Loop Control
- Engine Performance Diagnostics
- Minimum Engine-to-Engine Variation
- Minimum Cylinder-to-Cylinder Variation
- Transient Control
- Reduced Fuel Consumption

Ultra Fast NO_x Sensor - Spec's

- Accuracy
  - ≤ 4% of Full Range
  - < 5% Drift Over Life Time
- Response
  - 8 - 10 milliseconds
  - < 100 milliseconds for SCR
- Temperature Range
  - -40 to 700° C
- Life
  - B_{10} > 5,000 Hours Light Duty On-Highway
  - B_{10} > 40,000 Hours Heavy Duty On-Highway
  - B_{10} > 80,000 Hours Off-Highway

Particulate Sensor - Closed Loop Control

- Accuracy = ≤ 300 Parts per Billion
- Resolution = ≤ 75 Parts per Billion
- Response
  - 8 - 10 milliseconds
- Temperature Range
  - -40 to 700° C
- Life
  - B_{10} > 5,000 Hours Light Duty On-Highway
  - B_{10} > 40,000 Hours Heavy Duty On-Highway
  - B_{10} > 80,000 Hours Off-Highway

Summary of Program Needs

- Combustion Modeling & Optimization
- Variable Orifice Nozzle for Diesel Injection
- Gas Engine Application to Locomotive
- NO_x Sensor Development
- Package Optimized After-Treatment

Changing Technology